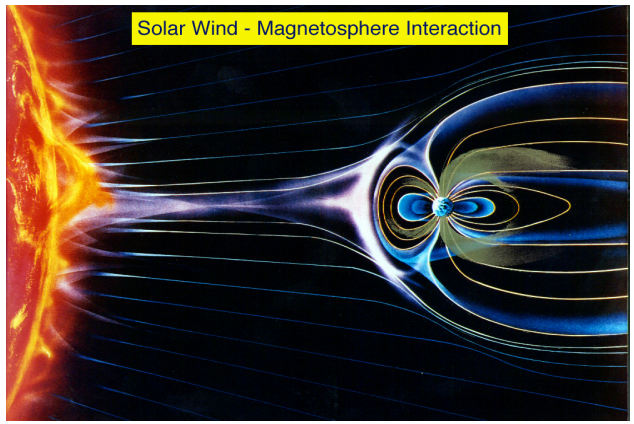
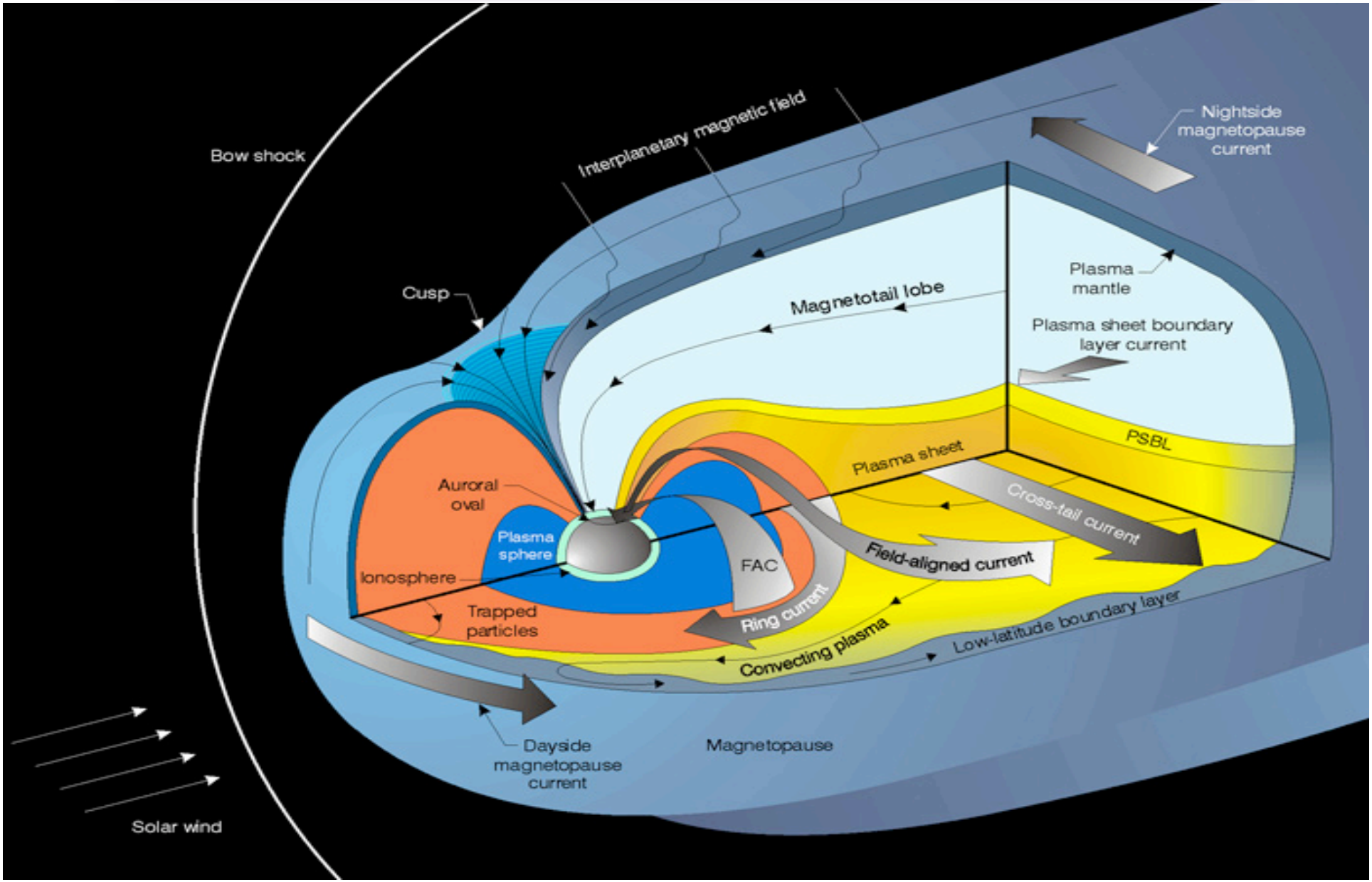
The Scientific Motivation of Space Cubesat Platforms

George V. Khazanov

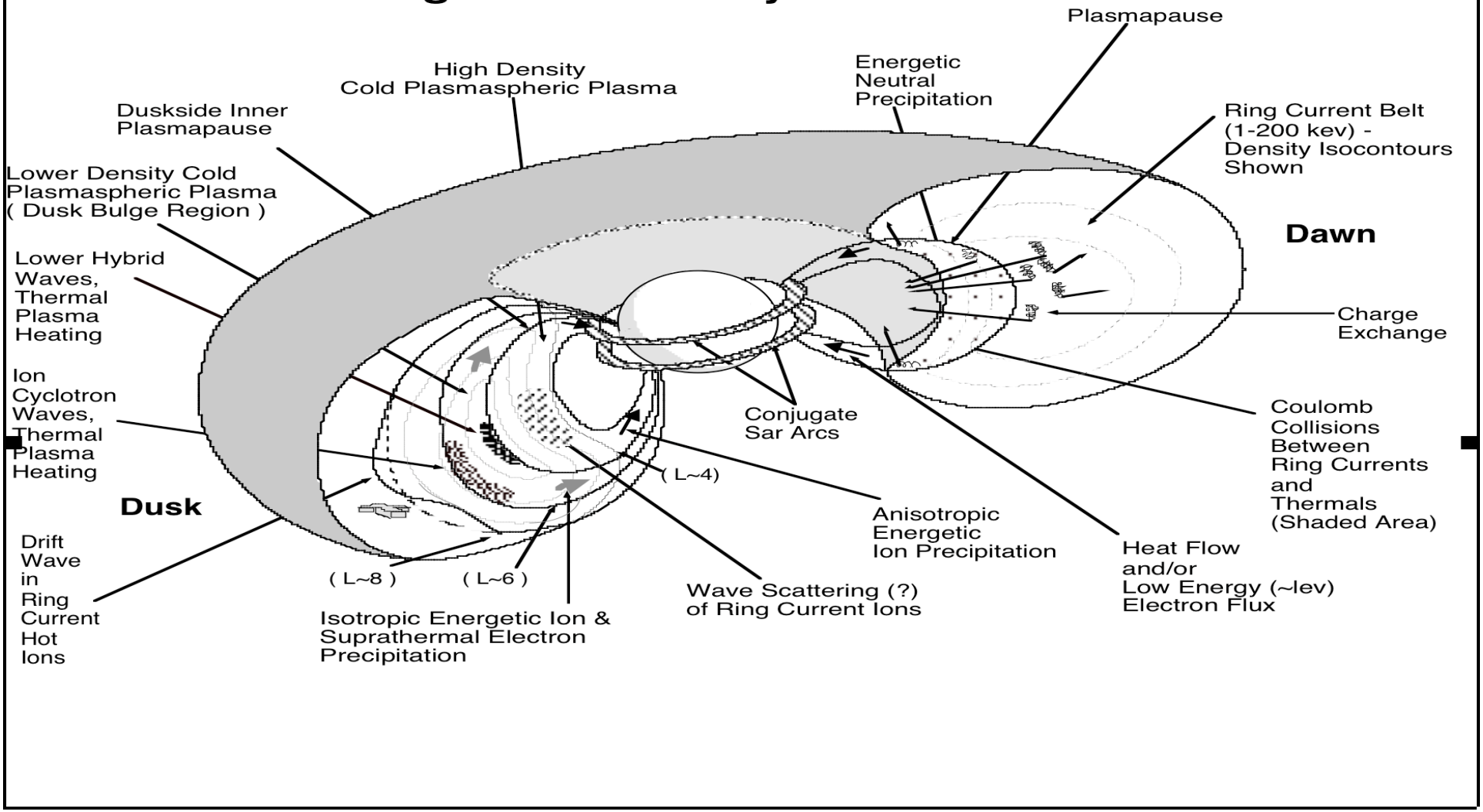
NASA Goddard Space Flight Center, USA



The Terrestrial Magnetosphere

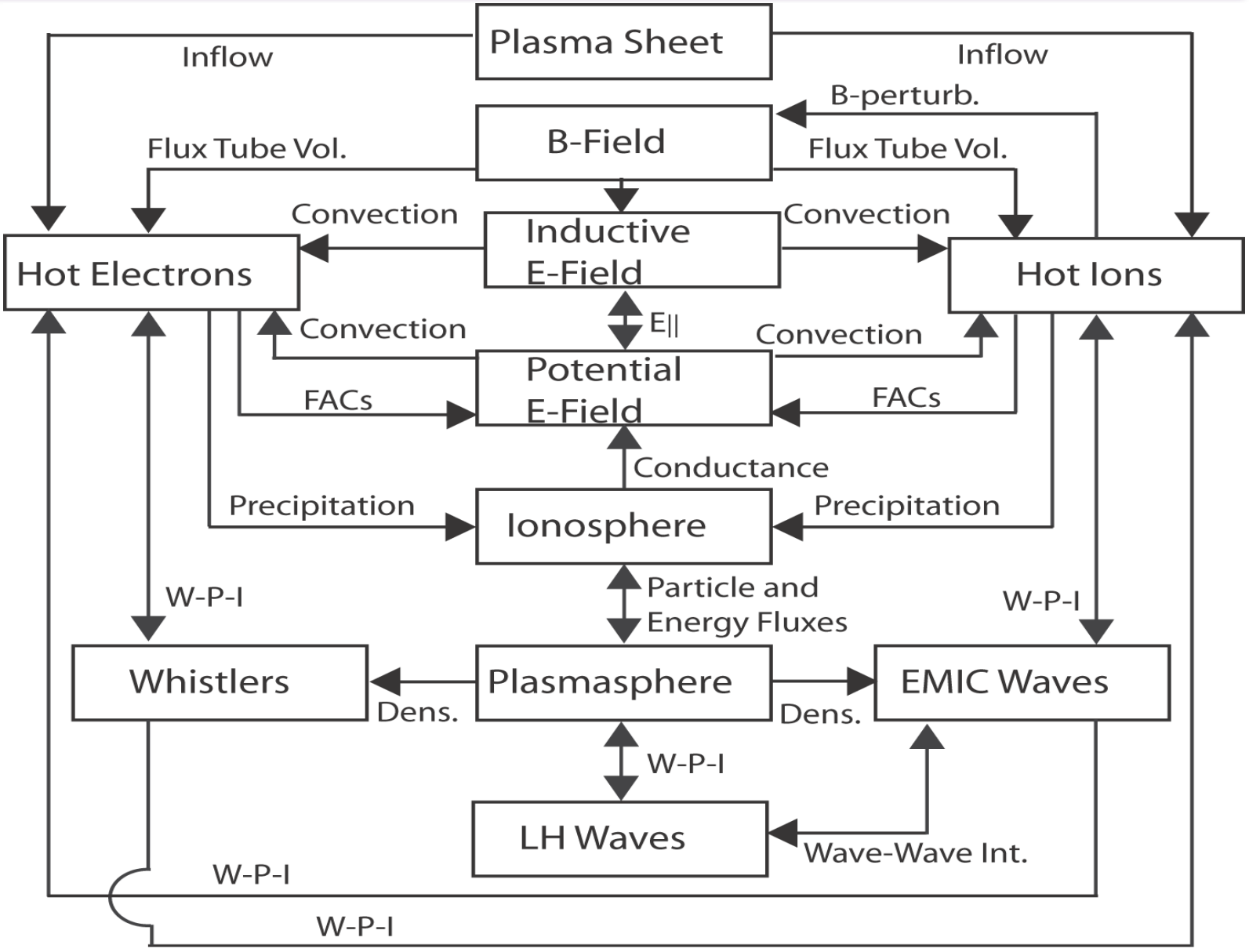


Ring Current Decay Processes



Population	Density	Temperature	Source	Composition	Driver	Importance
Plasmasphere	100s cm^{-3} to 1000s	< 1 eV, maybe up to 10s of eV	Subauroral ionosphere	H^+, some He^+ and O^+	E-field	Dominates mass density
Ring Current	~few cm^{-3} up to 10s	1-400 keV	Plasma sheet (SW and iono)	H^+, O^+ in storms	E and B fields	Dominates energy density
Radiation Belts	<<1 cm^{-3}	100s of keV toMeV	Plasma sheet, SEP's, local acc.	Mostly e^-, some H^+	B-field	Dominates S/C Damage

IM Cross Scale Coupling Loop



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George V. Khazanov

Kinetic Theory of the Inner Magnetospheric Plasma

ASSL

Springer

Motivation

Budgets are at best flat; Launch costs are rising *rapidly,* limiting flight opportunities, and eating into available mission funds

Also

Scientifically we need simultaneous measurements: constellations and system science observatories. Small spacecraft enable this science.

Technology now allows us to fly small spacecraft with capabilities similar to the larger s/c. This allows:

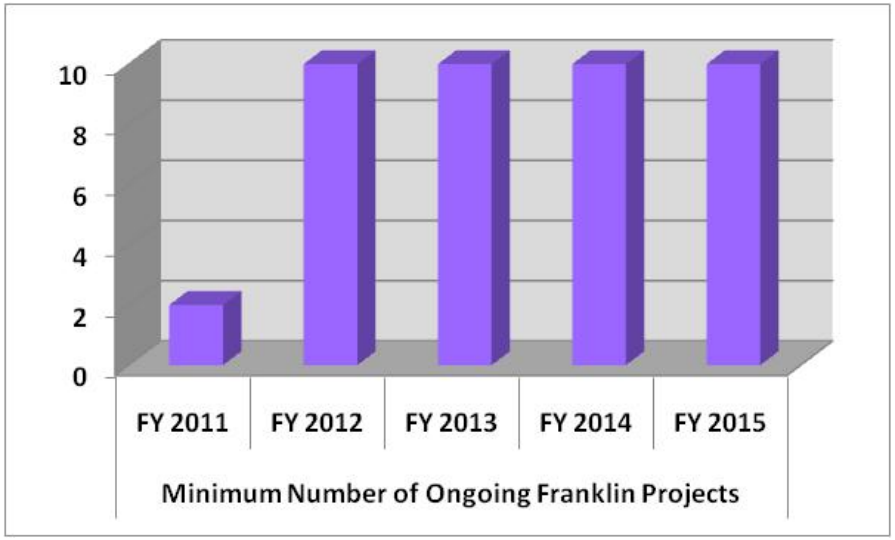
- More flight opportunities (rideshares, e.g.)
- Constellations (>50 satellites) & system science (think original ISTP & LWS)

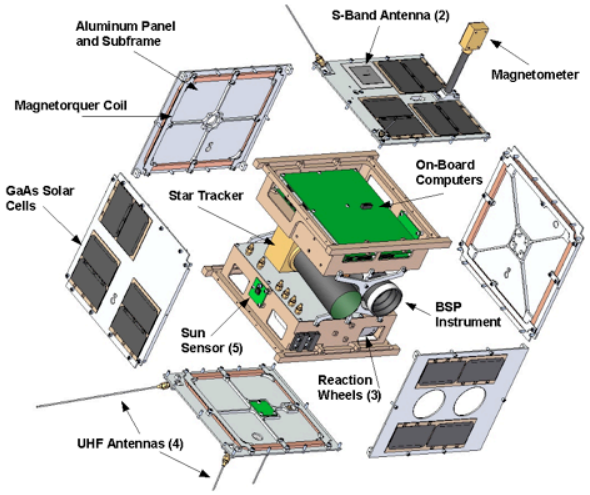
The landscape

- NSF has a highly popular and over-subscribed cubesat program
  - ~1M/spacecraft.
- NASA's 2011 Cubesat Launch Initiative received 31 proposals, 20 were selected (at least 3 at GSFC)
- GSFC has at least 5 cubesats under development
  - 2 hosted in code 500, 3 in 670
- NASA has now explicitly added cubesats to the SR&T/LCAS announcement.

OCT Small Spacecraft Programs
Franklin Small Satellite Subsystem Technology Program

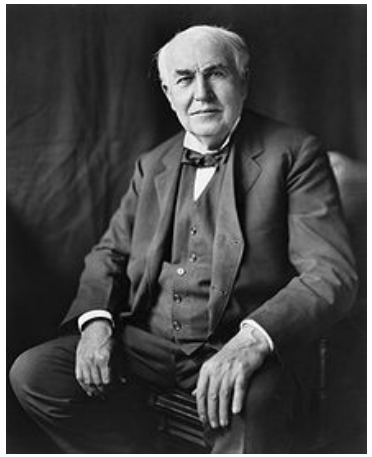
- **Objectives:** The Franklin Program will mature technologies that enable small satellites to provide game changing capabilities for the government and commercial sectors. At completion, the subsystem deliverables should be ready for demonstration in space.
- **TRL Maturation:** From TRL 3-4 to TRL 5-6
- **Solicitation:** Annual BAA. At least 2-8 competitively selected awards.
- **Awards:** One-year base activity with two, one-year options. Estimate $1-3 million per year.
- **Collaboration:** Competitions open to academia, industry, and federal laboratories with partnering strongly encouraged.

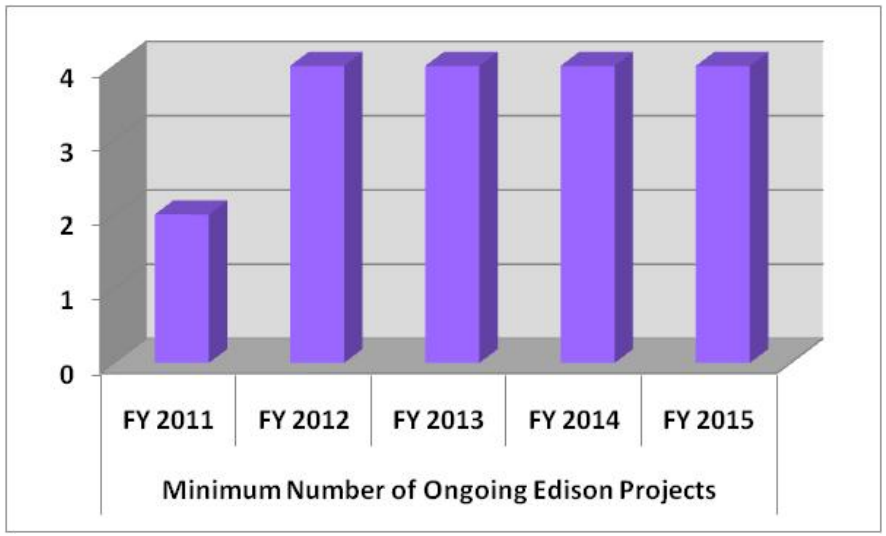


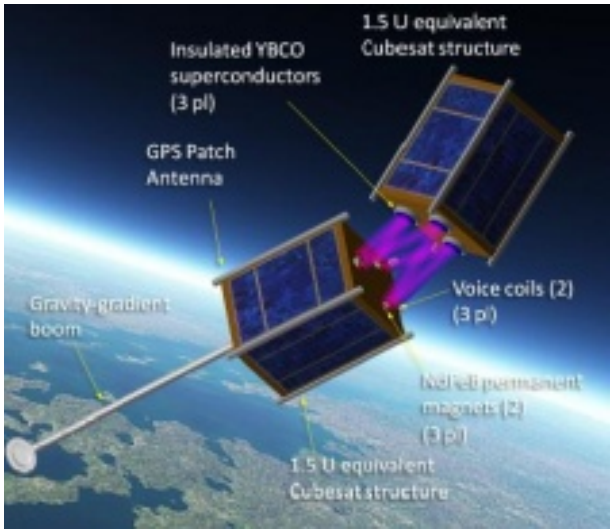


OCT Small Spacecraft Programs
Edison Small Satellite Demonstration Mission Program

- **Objectives:** Develop and operate a series of small satellite technology demonstration missions with game-changing and crosscutting potential for government and commercial sectors. Provide science and educational missions of opportunities as secondary objectives. Improve secondary payload space access.
- **TRL Maturation:** From TRL 5-6 to TRL 6-7
- **Solicitation:** Annual BAA. At least 1-2 competitively selected awards.
- **Awards:** Two years to launch readiness with development and launch gates. Estimate $1-10 million total mission cost range.
- **Collaboration:** Competitions open to academia, industry, and federal laboratories with partnering strongly encouraged.







CINEMA

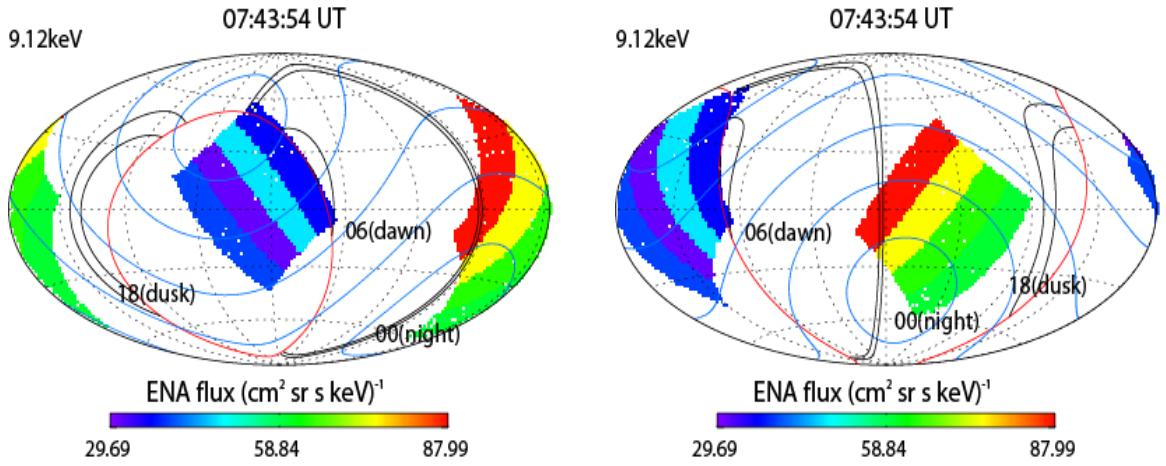
CubeSat for Ions, Neutrals, Electrons, MAgnetic fields

Collaborating Institutions

- **UC Berkeley/SSL** (Lead Institution)
  - A World Leader in Space Weather Research
  - Developing Compact Suprathermal Particle Instruments
  - Experienced in Spinning Spacecraft ACS
  - Formal (NASA) and “Informal” (Sounding Rockets) Flight Experience
- **Imperial College London, Space Magnetometer Laboratory**
  - Fluxgate Magnetometers on Cassini, Cluster
  - Developing Small, Low-mass Magnetometers for CubeSats
- **NASA Ames**
  - Cubesat Experience (GeneSat, PharmaSat, O/OREOs)
  - Possible Contribution of GeneSat Avionics
- **Kyung Hee University (S. Korea)**
  - World Class University project
  - Space Weather Research

CINEMA Science

- Magnetic Storms and Ring Current
  - Image ring current particles in local time
  - Observation of approximately equatorial ring current fluxes
- High Latitude Charged Particle Precipitation
  - Will measure ~4-100 KeV ion precipitation in-situ and remotely sense ion precipitation with Energetic Neutral Atoms (ENAs)

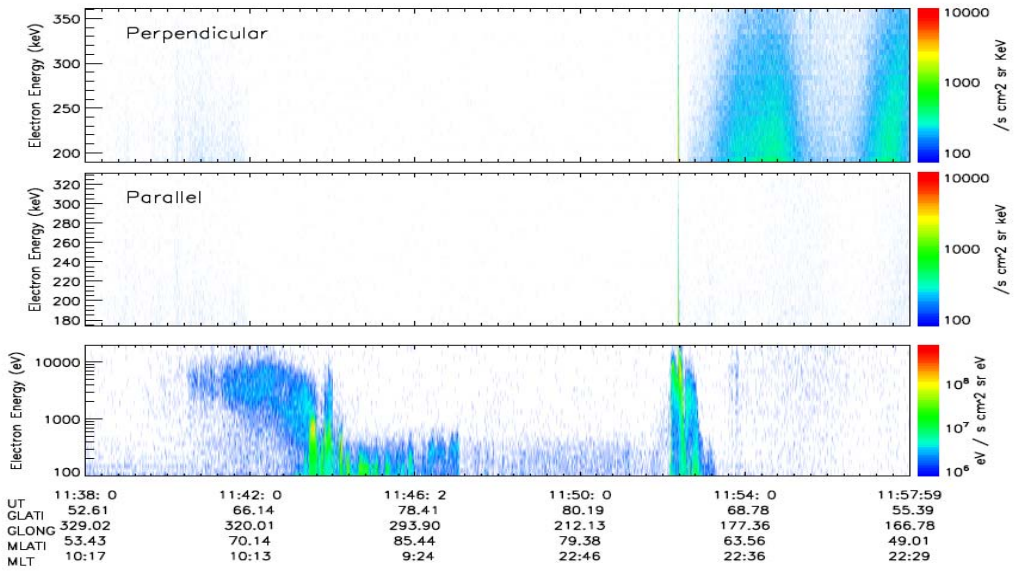


ENA map from STE instrument on STEREO

CINEMA Science

- Electron Microbursts (0.10 – 0.25 sec)
  - Measure precipitated electrons and ions with a single detector
  - Used to study microbursts, pulsations and other precipitation structures
- Magnetic Field
  - For interpreting particle detector measurements
  - Waves and Currents
  - Track Phase Fronts of
    - Ultra-low Frequency waves (0.1 Hz or lower)
    - Flux Transfer Events (FTEs) - quasi-periodic reconnection events at the Earth's magnetopause
- Multi-Satellite Science
  - Multi-Point Measurements
  - Stereo Observations

Multi-Satellite Science



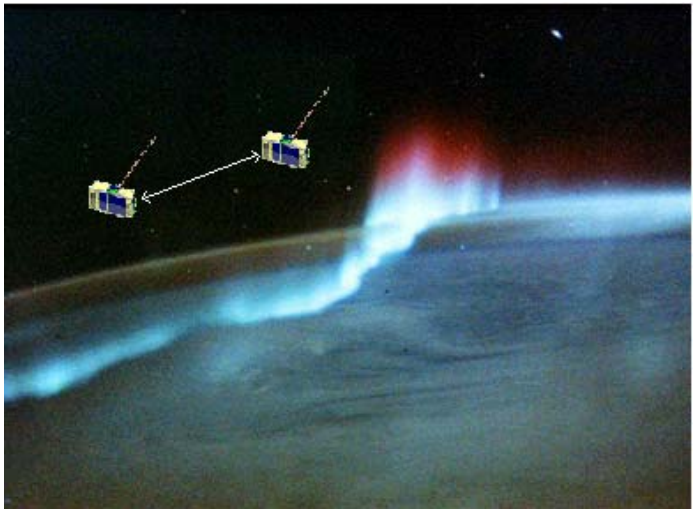
Separation Speed: 1m/min

1 d: 1.4 km

10 d: 14 km

1 m: 42 km

1y: 504 km

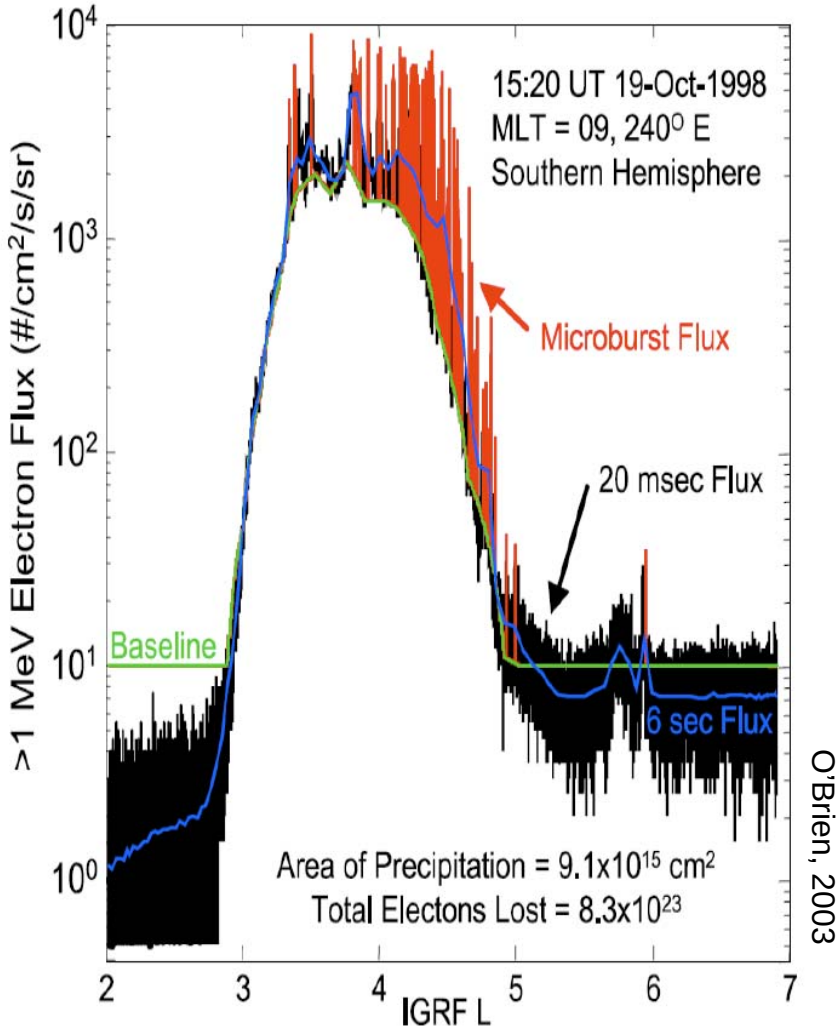


Spatial or Time Variation
“Is it local acceleration?”

Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics (FIREBIRD)

Electrons lost in microbursts

- Work by O'Brien (2003)
  - Calculate total number lost by integrating over time and space (with some basic assumptions)
- FIREBIRD contribution: by bringing in objectives 1 and 2 along with concurrent measurements, probability models, etc this can be further addressed



O'Brien, 2003

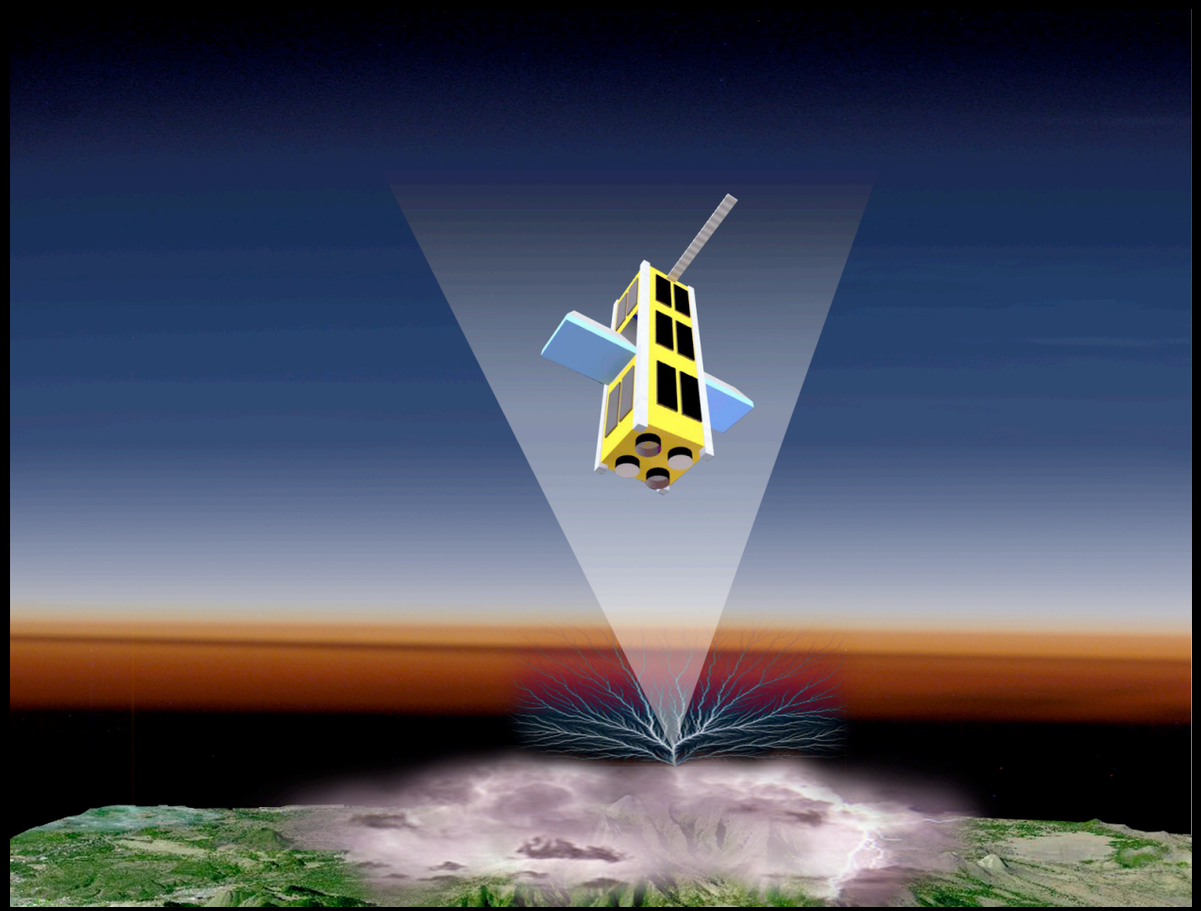
MONTANA STATE UNIVERSITY Mountains and Minds

BOSTON UNIVERSITY

AEROSPACE

The Firefly Mission

Understanding Earth's most powerful natural particle accelerator



CubeSat Developers' Workshop

Mysterious TGFs

- The Earth as a source of gamma rays?
- Lightning as an antimatter factory
- Lightning source for inner belt electrons?
- Why and how does lightning occur?
- Does all lightning produce energetic radiation?
- What about other planets?
- How does activity in the troposphere affect the chemistry and plasma populations at 80-100 km?

Instruments

Gamma Ray Detector (GRD) measures:

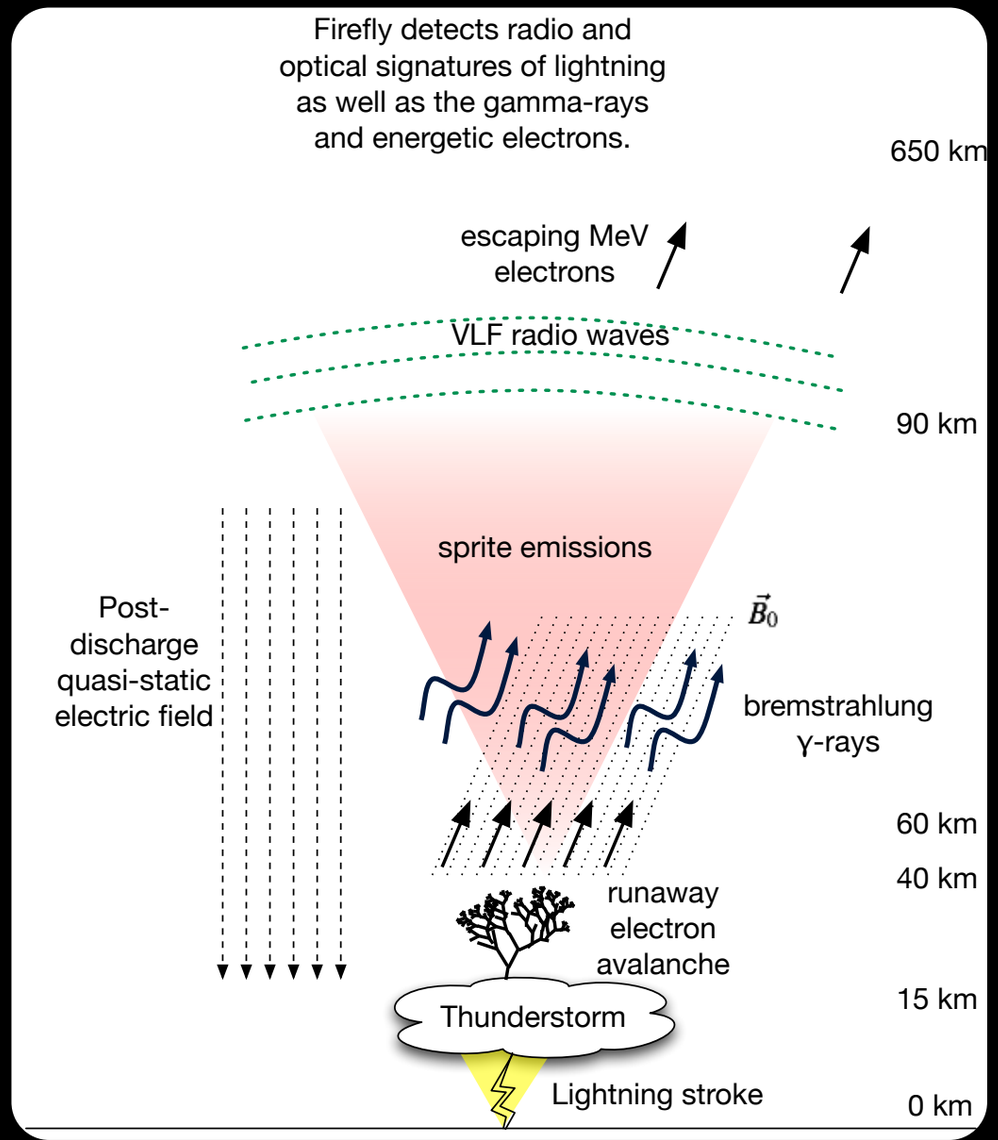
photons from 20 keV to 20 MeV, at count rates up to 1 MHz
electrons from 100 keV to 10 MeV, at count rates up to 300 kHz
"counts" up to 10 MHz
snapshots, spectra, and count rate histograms

VLF wave receiver (VLF) measures:

single-axis electric fields 100 Hz to 20 kHz, up to 10 mV/m

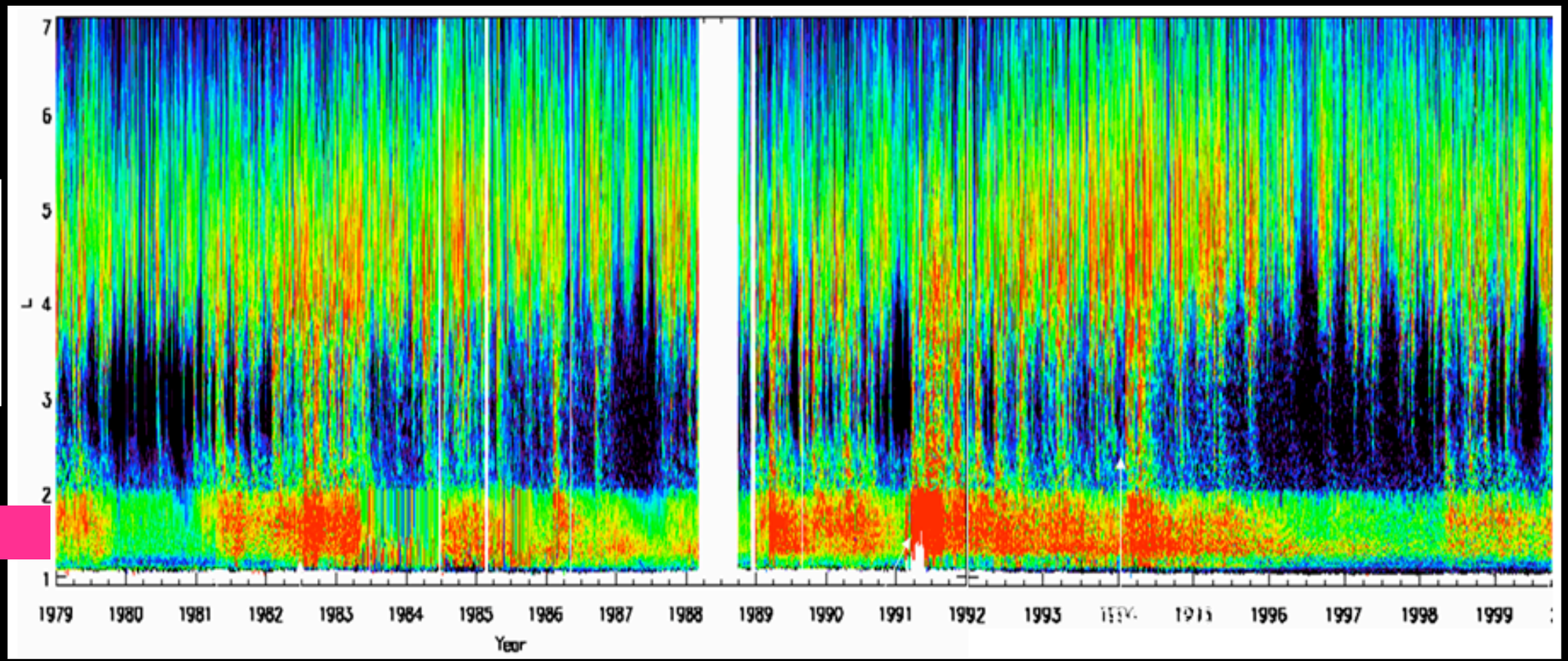
Optical photodiode (OPD) measures:

four FOV light levels 100 Hz to 20 kHz, saturates above 98 %ile lightning
provides localization of lightning to one of twelve regions (overlap of FOVs)
can see lightning within about 400 km horizontal distance
designed to work day and night



Radiation Belt Access

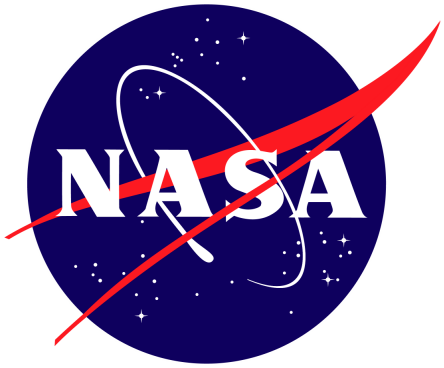
Region of significant TGF occurrence



X. Shao

The Future

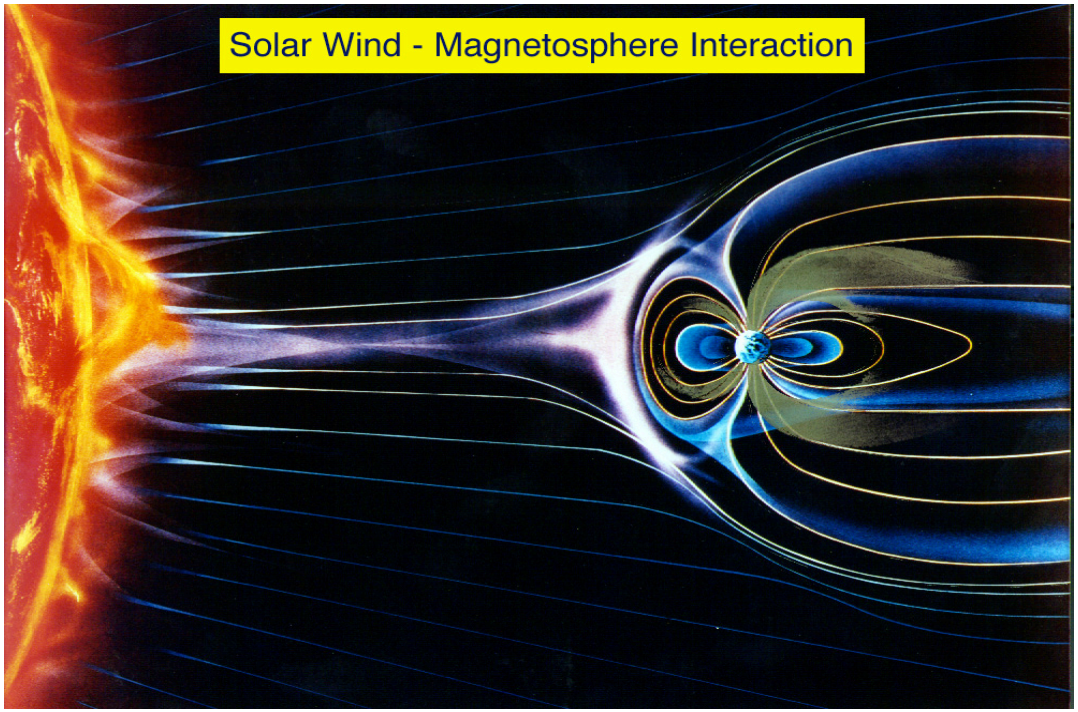
- Explorer missions utilizing cubesats have been developed. These are *serious* missions, addressing critical science questions that larger spacecraft *cannot* answer: Constellation science, E-region science.
- The needs of small satellites are driving a renaissance of instrument and sub-system miniaturization
- The Office of Chief Technologist has seen the light: Edison (small satellite demonstration) and Franklin (small satellite subsystems) initiatives.



Thanks For Your Attention

Students, Apply !

NASA
Postdoctoral Program
administered by Oak Ridge Associated Universities



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